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Geospatial Data Analysis Corporation
Monitoring The World, For A Better Tomorrow

Assessment of the Radiometric Calibration of PlanetScope 2 Dove Imagery

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Goal & Main Results

Goal:

Assess the radiometric calibration of the PlanetScope 2 TOA imagery by cross-comparing it with "gold" standard Landsat 8 TOA data

Main Result:

PlanetScope 2 imagery exhibits high correlation with co-incident / co-located Landsat 8 imagery. High correlation observed across all analyzed locations, dates, PlanetScope 2 sensors, bands, and LC types

Acquired Imagery

- **Access:** Planet Data API v1
- **Imagery Dates:** Jan 01, 2016 – Feb 01, 2017
- **AOIs:** 12 Landsat footprints over 3 countries;
Represent various LCs, both invariant & seasonal
- **LT8 Imagery:** 91 scene; CC<25%
- **Dove Imagery:** PlanetScope 2 generation
Co-incident / Co-located with LT8 +/-3 hours
4,577 scenes reported
4,067 scenes downloaded (which had full meta & UDM*)

(*) UDM – Unusable Data Masks; pixel level masks supplied by Planet

Acquired Imagery

- PlanetScope 2 generation (*i.e.*, operational)
- 31 different PlanetScope 2 satellites
Between 14 to 248 scenes were acquired for each satellite ID
- Level 3B (Ortho Scene) products
Radiometrically corrected to top-of-atmosphere (TOA) radiance; orthorectified, projected to a cartographic projection (UTM); 3.0m GSD
- 2,401 scene: ISS orbit; 1,666 scenes: SSO
ISS – International Space Station orbit (altitude: ~420 km; equator crossing time: varies; resolution: ~3m)
SSO -- Sun-Synchronous Orbit (altitude: ~475 km; equator crossing time: 9:30-11:30am; resolution: ~3.7m)
- ~44 PlanetScope 2 scenes per 1 Landsat scene

Data Processing

- Converted all imagery to TOA
- Re-projected and down-sampled PlanetScope 2 imagery to match coincident Landsat 8
- Applied data gaps masks (QA+UDM) to each co-incident/co-located Landsat 8 / PlanetScope 2 pair
- Extracted ~5 million cloud-free sample points from co-incident/co-located images (data gaps excluded; random sample)
- Extracted pseudo-invariant points to model variations among PlanetScope 2 satellites
 - Removed non-invariant LC types according to a LC map
 - Removed the effects of LC variation and change between Landsat 8 images over time. Kept only pixels with similar values over time (within 2% reflectance in all bands)
 - Removed points where Landsat 8 and PlanetScope 2 values differed by more than 50% (assumed cloud, atmosphere contaminated)
 - Final set: 40,000 to 60,000 training points per each target spectral profile, representing 32 distinct PlanetScope 2 satellite IDs and both orbits

PS₂ / LT8 Correlations

- High correlation between PlanetScope 2 and Landsat 8 imagery (0.86 to 0.95 in R^2)
- High correlation observed across all analyzed locations, dates, LC types, and PlanetScope 2 sensors and bands (Red band has the highest correlation)

PlanetScope 2 Correlation with Landsat 8 (TOA Reflectances, R^2)

Model	Blue Band Accuracy	Green Band Accuracy	Red Band Accuracy	NIR Band Accuracy
Ridge Regression	0.866 +/- 0.005	0.910 +/- 0.004	0.924 +/- 0.001	0.880 +/- 0.003
Lasso Regression	0.852 +/- 0.003	0.898 +/- 0.001	0.918 +/- 0.001	0.872 +/- 0.003
Regression Tree	0.915 +/- 0.001	0.943 +/- 0.002	0.948 +/- 0.001	0.921 +/- 0.003
Random Forest	0.923 +/- 0.001	0.948 +/- 0.002	0.951 +/- 0.000	0.927 +/- 0.002

Band Predictions

- PlanetScope 2 Green, Red, and NIR bands are the most important predictive variables for the corresponding Landsat 8 spectral band
- Landsat 8 Blue band is not predicted well by the PlanetScope 2 Blue band
- Landsat Blue band is more accurately predicted by the PlanetScope 2 Green band
 - ✓ *Due to overlap between the PlanetScope 2 Green band with Landsat Blue band?*
 - ✓ *Due to higher atm contamination of PlanetScope 2 Blue band (vs Landsat Blue band)?*

Calibration-to-Landsat Coefficients of the Spectral Bands
(Ridge Regression Model)

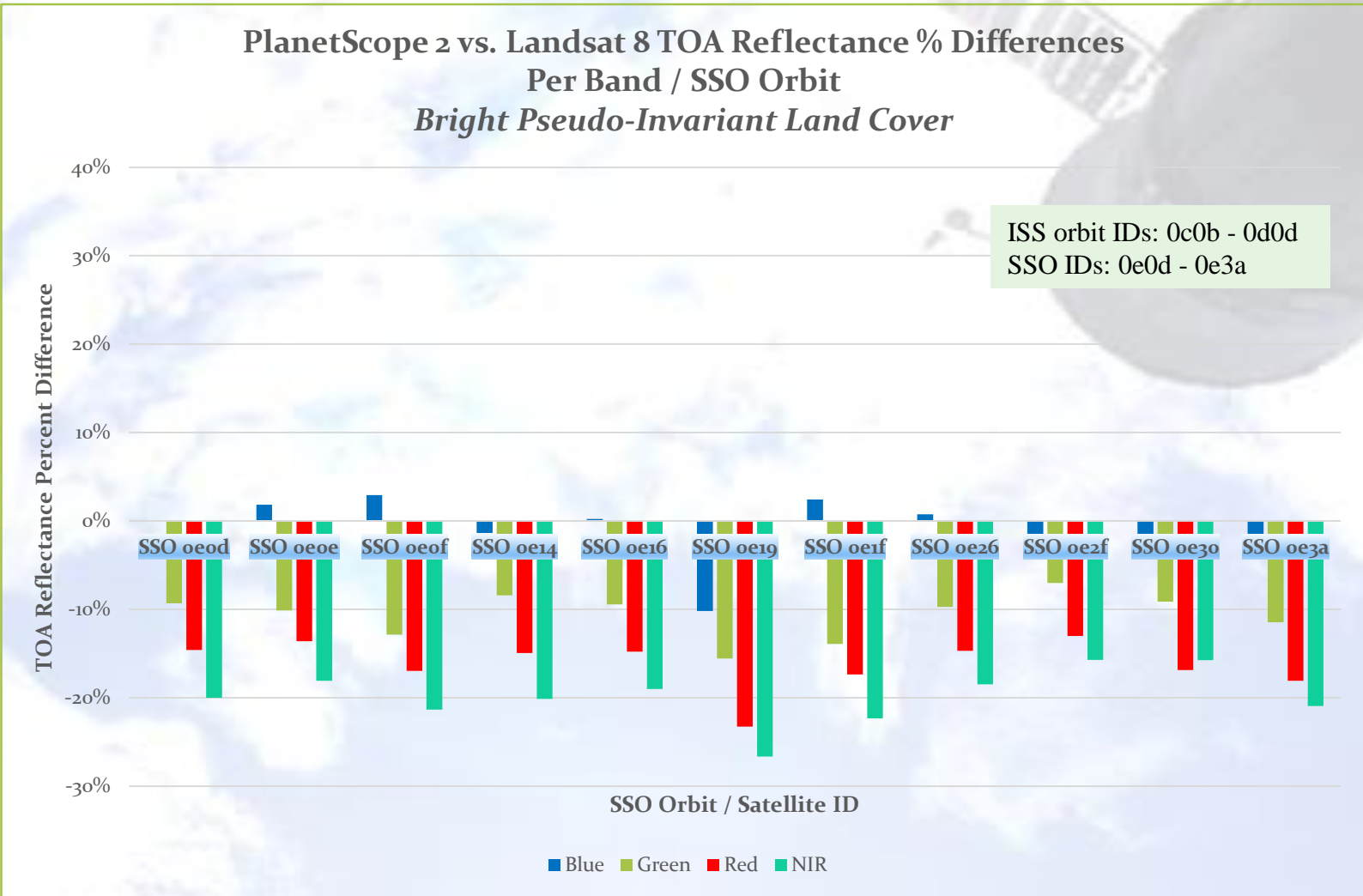
Input Variable	Landsat Blue	Landsat Green	Landsat Red	Landsat NIR
PlanetScope Blue	0.051	-0.602	-0.129	0.278
PlanetScope Green	0.970	1.544	-0.344	-0.196
PlanetScope Red	-0.117	0.122	1.619	-0.089
PlanetScope NIR	-0.135	-0.124	-0.187	0.975

Sensor	Blue Band	Green Band	Red Band	NIR Band
Landsat 8	450-510 nm	530-590 nm	630-670 nm	850-880 nm
PlanetScope 2 Doves	455-515 nm	500-590 nm	590-670 nm	780-860 nm

Per Satellite Effects

Small but measurable and repeatable variability in TOA reflectances is observed per PlanetScope 2 orbit, satellite, and spectral band (for bright pseudo-invariant land cover types)

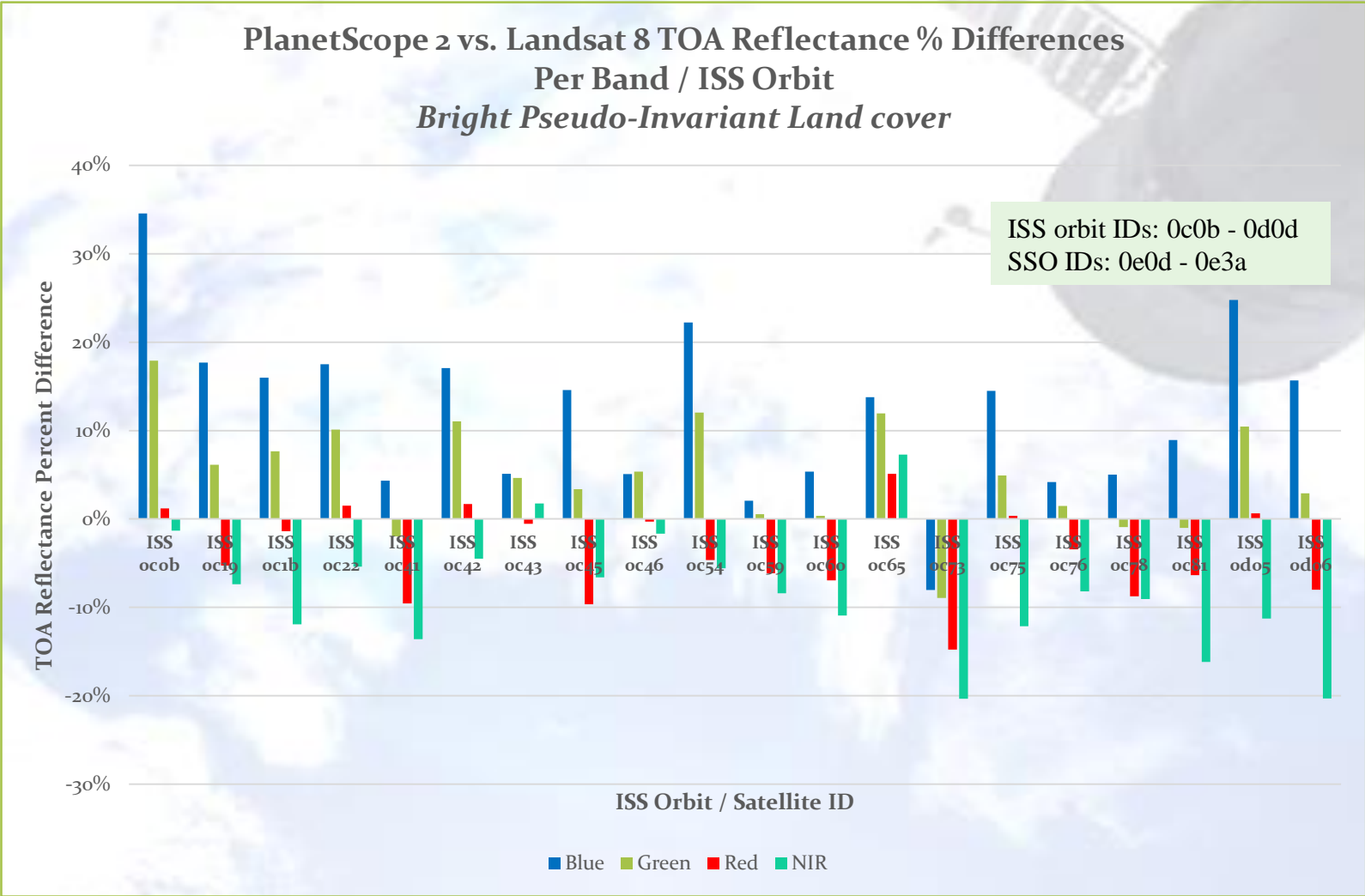
The PlanetScope 2 SSO sensors tend to report lower (vs Landsat 8) TOA reflectances for all bands





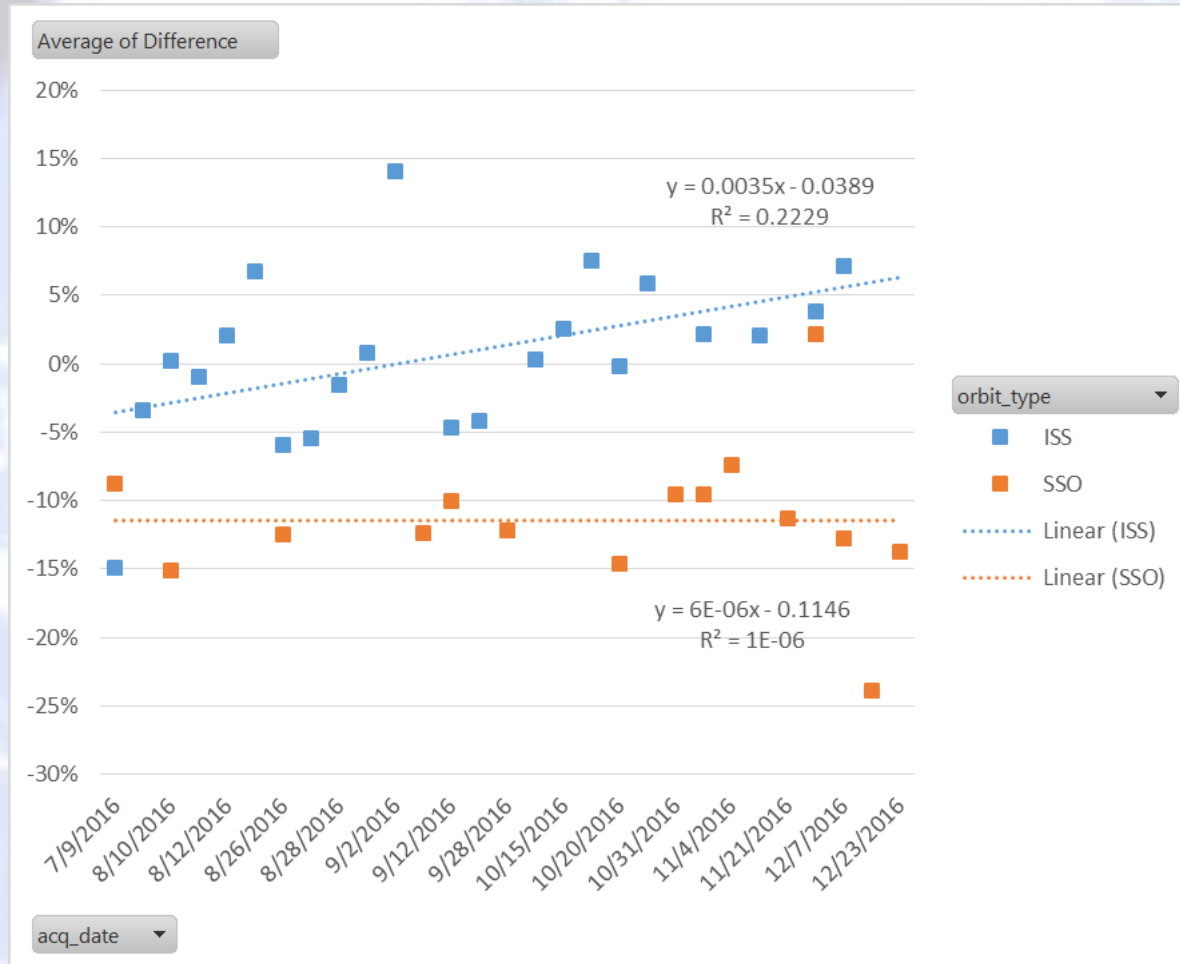
Per Satellite Effects

The PlanetScope 2 ISS orbit sensors tend to report higher (vs LT8) TOA reflectances in Blue band and lower TOA reflectances in the lower frequencies



ISS / SSO Effects

PlanetScope 2 vs Landsat 8 Average % Reflectance Difference (bright pseudo-invariant LC, all AOIs, sensor and band averages)



- PlanetScope 2 ISS scenes seem to be brighter than Landsat 8
- PlanetScope 2 SSO scenes seem to be darker than Landsat 8
- Indications of a temporal trend in PlanetScope 2 imagery overall brightness
 - SSO: Slight decrease? Stable?*
 - ISS : Increase?*
 - Inconclusive (insufficient repeat imagery)*

Conclusions

- High correlation between co-incident / co-located PlanetScope 2 and Landsat 8 imagery
 - R^2 : 0.85 to 0.95
 - Across all analyzed locations, dates, PlanetScope 2 sensors, bands, and LC types
 - Red band has the highest correlation
- PlanetScope 2 Green, Red, and NIR band value is the most important predictor for the corresponding Landsat 8 spectral band
- PlanetScope 2 Green band is the most important predictor for Landsat 8 Blue band

Conclusions

- For bright pseudo-invariant LC types: A small but measurable and repeatable variability in PlanetScope 2 TOA reflectances per orbit, satellite, and spectral band
 - SSO imagery:
 - Tends to be darker than Landsat 8
 - Tend to report lower values for all bands than Landsat 8
 - Indications of either a stable values or a slight decrease in overall brightness over time
 - ISS imagery :
 - Tends to be brighter than Landsat 8
 - Tend to report higher values in Blue band than Landsat 8
 - Tends to report lower values in Green, Red, and NIR than Landsat 8
 - Indications of a slight increase in overall brightness over time
- PlanetScope 2 calibration may be further improved by calibration to the surface reflectances



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THANK YOU!